Real-Time Remediation Utilizing the Backpack Sodium Iodide System and the U.S. EPA Triad Approach

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ABSTRACT

Real-time characterization during remediation activities is being accomplished at the Idaho National Laboratory (INL) with the use of the backpack sodium iodide system (BaSIS). The BaSIS is comprised of a 3-in. by 5-in. sodium iodide (NaI) detector, differential corrected global positioning system (GPS), and portable computer, integrated into a lightweight backpack deployment platform. The system is operated with specialized software that allows the operator and/or remediation field manager to view data as they are collected. Upon completion of planned excavation stages, the area is surveyed for residual radiological contamination. After data collection is complete, data is available to the remediation field manager as a contour map showing the area(s) that require further excavation. The use of real-time measurement systems, rapid turn-around time of data, and dynamic work strategy support the U.S. Environmental Protection Agency's (EPA) Triad approach. Decisions are made in real-time as to the need for further remediation.

This paper describes the BaSIS system calibration, testing and use, and outlines negotiations with the appropriate CERCLA regulatory agencies (U.S. Environmental Protection Agency, Idaho Department of Environmental Quality, and U.S. Department of Energy Idaho Operations Office) to allow the use of real-time instrumentation during the remediation process, and for confirmation surveys. By using the BaSIS in such a manner, the INL seeks to demonstrate compliance with remediation objectives.

INTRODUCTION

The approach to Superfund site remediation performed in accordance with the Comprehensive Environmental Response, Conservation, and Liability Act (CERCLA) has traditionally followed a rigorous and formalized approach with regard to site evaluation, investigation, risk assessment, remediation and final closure. This rigid process was developed to ensure consistent mitigation of unacceptable risk associated hazardous material release sites across the country.

The U. S. Department of Energy, in conjunction with the State of Idaho and the U. S. Environmental Protection Agency signed the *Federal Facility Agreement and Consent Order for the Idaho National Engineering Laboratory* (FFA/CO) [1] in 1991 that has provided the roadmap to closure for CERCLA activities at the Idaho National Laboratory. Site investigation, risk assessment and remedial actions at the INL have followed the traditional CERCLA process, with adherence to EPA guidance.

Recent guidance for site cleanup from EPA has manifested itself as the Triad approach [2]. This paper describes how the EPA Triad approach was implemented to expedite site remediation through a process identified as real-time remediation. Real-time remediation at the INL is the dynamic work strategy that focuses on the use of real-time measurement systems to guide projects to completion in a rapid and efficient manner.

THE TRIAD APPROACH AT THE IDAHO CLEANUP PROJECT

The U.S. Department of Energy Idaho Operations Office has accelerated the cleanup of the highest risk sites at the Idaho National Laboratory. Implementing the U.S. EPA Triad approach at the INL has allowed for expedited cleanup of radiologically contaminated soil. The Triad approach, as the name suggests, has three primary components that, when used together, effectively manage uncertainty associated with the remediation projects at the INL:

- Systematic project planning
- Dynamic work strategy
- Real-time measurements.

Systematic project planning has been an integral part of the CERCLA work process at the INL since the signing of the FFA/CO in 1991. Implementation of all Triad components at the INL included multiple meetings between representatives from the Idaho Cleanup Project (ICP) contractor, DOE-ID, the state of Idaho Department of Environmental Quality, and the U.S. EPA Region 10 to present the results of the detailed project planning that had been completed for the contaminated soil removal at Test Area North (TAN), and to describe how the other two elements (i.e., dynamic work strategy and real-time measurements) were going to be implemented during the remediation.

REAL-TIME INSTRUMENTATION

The dynamic work strategy for the soil removal at TAN was developed around the use of real-time field instrumentation. Previous investigations at the TAN site have shown that if the Cs-137 concentrations are below the 23 pCi/g remedial action goal, other contaminants of concern (COCs) (i.e., volatile and semi-volatile organic compounds) are also below their respective remedial action goals. As such, Cs-137 concentration in the soil, as measured with field instrumentation, can be used during remediation activities by project personnel to reliably predict when the remediation is complete.

The real-time instrumentation developed by the INL is configured to report Cs-137 concentrations in soil in units of pCi/g. The system is comprised of a sodium iodide (NaI) gamma-ray spectrometer, differential corrected global positioning system (DGPS), field-rugged system control computer, and field deployment platform (i.e., backpack). The hardware is configured for deployment using a field backpack (Figure 1) to allow for optimum portability in areas inaccessible to vehicle-based platforms. This system is identified as the Backpack Sodium Iodide System (BaSIS). Due to its portability, the noted advantages of the BaSIS include the ability to provide a mobile survey of excavated areas in a fraction of the time required to perform the surveys using an in situ high-purity germanium (HPGe) detector system.

Fig. 1. BaSIS real-time measurement system

The field rugged computer and real-time software package processes and integrates data from the NaI gamma-ray spectrometer and the DGPS. The real-time software provides a simple graphical user interface and push-button control of all system functions. Due to its high degree of portability, the BaSIS is used to provide 100% coverage of the area(s) of concern. The BaSIS provides a high density of discreet measurements with a maximum detector field of view diameter of 20 ft., thus increasing the spatial resolution of the survey four-fold over conventional measurements with an HPGe system. Additionally, the real-time software used in the BaSIS system minimizes time-consuming post-processing of the data. Detailed contour maps are made available to project personnel within minutes of completing the survey.

Key features of the BaSIS include:

- 100% coverage during characterization
- Identification and quantification (pCi/g) of Cs-137, with a minimum detectable concentration of 1.5 pCi/g for a 10-second count
- Real-time display of position and radionuclide concentrations during survey
- Continuous data collection (Scan Mode), or stationary measurements (Point & Shoot Mode)
- User-selectable threshold alarms that alert operator to activity exceeding limits
- Lightweight backpack system can be used nearly every where a person can walk
- Real-time data management software provides
    - Automated data collection
    - Automated QA/QC functions for system and data
    - Automated mapping function

  - Automated data archiving

BaSIS Calibration

The BaSIS was calibrated against the HPGe system currently used for field measurements. This calibration served two purposes: 1) provide calibration coefficients for the BaSIS system to allow for conversion of net count rate data to Cs-137 concentrations (in soil) in units of pCi/g, and 2) to provide a basis of comparability between the two systems. The HPGe systems are calibrated using National Institute of Standards (NIST) traceable standards, and serve as the benchmark for the BaSIS system response. The BaSIS was calibrated to provide Cs-137 concentrations in soil in units of pCi/g.

Calibration of the BaSIS system was performed in a two-step process: 1) energy calibration and 2) efficiency calibration. The energy calibration was performed in the field at the calibration measurement point B25, where the Cs-137 concentration was reported as 10.1 ± 0.2 pCi/g. The BaSIS was calibrated using three gamma-ray energies, as identified in Table I. The energy calibration is used by the BaSIS system to properly identify the signal produced by Cs-137.

Table I. BaSIS Energy Calibration Table

Peak Energy, keV	**Channel**
661.62	232
1,460.83	500
2,614.53	883

The efficiency calibration of the BaSIS system involved side-by-side measurements of ten pre-selected points (Table II) with both the BaSIS and the standard HPGe system. The detectors were positioned at a height of 1-meter above the selected locations. Gamma-ray spectra were acquired with each system using detector live times of 5 minutes and 15 minutes, respectively, for the BaSIS and the HPGe systems. The gamma-ray spectra from the HPGe system were analyzed using the M1 protocol [3] and results for the Cs-137 concentrations reported along with 1-sigma uncertainties. The gamma-ray spectra from the NaI detector in the BaSIS were also analyzed, and the net count rates for Cs-137 were calculated. Table II provides the results of the BaSIS and HPGe efficiency calibration measurements.

Table II. BaSIS Efficiency Calibration Measurement Results

Point ID	**BaSIS Data Cs-137 Count Rate**		**HPGe Data Cs 137 pCi/g**	
	cps	**1σ**	**Activity**	**1σ**
B14	73.4	1.0	5.6	0.2
B15	36.3	0.9	2.5	0.1
B25	133.3	1.2	10.1	0.2
B26	42.5	0.9	3.9	0.1
B28	15. 7	0.8	1.8	0.1
B29	12.5	0.8	1.4	0.1
B47	120.9	1.2	8.3	0.2
B48	81.5	1.0	6. 2	0.1
B51	25.7	0.9	2.1	0.1
B52	14.5	0.8	1.3	0.1

These data were then plotted, and a linear regression performed to determine the conversion factor for converting the net count rates in counts per second from the Cs-137 region of interest in the gamma-ray spectra collected by the BaSIS to a Cs-137 concentration in soil in pCi/g as shown in Fig. 2.

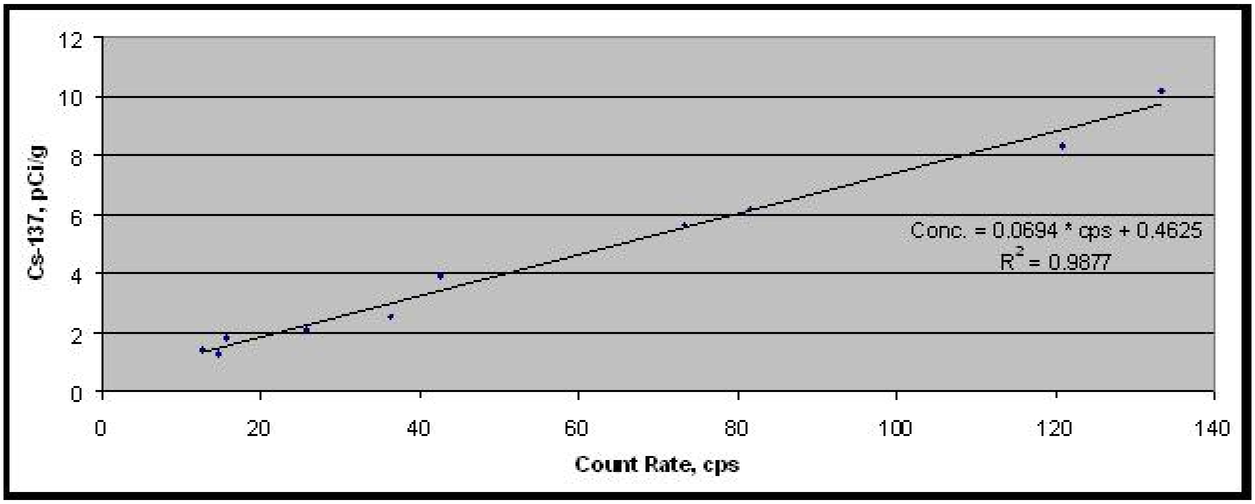

Fig. 2. BaSIS calibration regression plot and regression equation

As shown in Fig. 2 a simple linear regression provides a good fit to the data (i.e., $R^2 = 0.9877$). This equation has been hard-coded into the BaSIS operating software for real-time calculation of Cs-137 concentrations in soil.

BaSIS Field Testing

The BaSIS can collect data in two modes; 1) Scan and 2) Point-and-Shoot. The scan mode was designed to allow scanning, or moving measurements to be made over relatively large areas. While in scan mode, the BaSIS system software collects 10-second spectra from the NaI detector, calculates the Cs-137 concentration, and provides a differential corrected GPS position for each location. The geographic position assigned to each measurement corresponds to the midpoint between the location where the measurement started and where the measurement ended. The lower limit of detection for the 10-second spectra collected in scan mode is 1.2 pCi/g at the 95% confidence level. The point-and-shoot mode was designed to collect gamma-ray spectra at specific, fixed locations for a count time of 5 minutes. The 5-minute count time increases the precision of the measurement, and lowers the detection limit for Cs-137 to 0.6 pCi/g at the 95% confidence level.

After calibration of the BaSIS for energy and efficiency, a field test was performed at a known contamination site at the TAN facility where stockpiles of Cs-137 contaminated soil had been placed. Prior to using the BaSIS in this area, the soil stockpiles had been removed. The test area was approximately 100 ft. wide by 250 ft. long, and is located immediately to the northeast of the V-Tank remediation area. The field testing of the BaSIS system included the functionality of the system in scan, and point-and-shoot modes. Additionally, a comparability study was performed between the BaSIS and the existing HPGe system. Figure 3 shows the location and results of the

BaSIS and HPGe system field tests. The results of the comparison between the BaSIS and the HPGe are summarized in Table III.

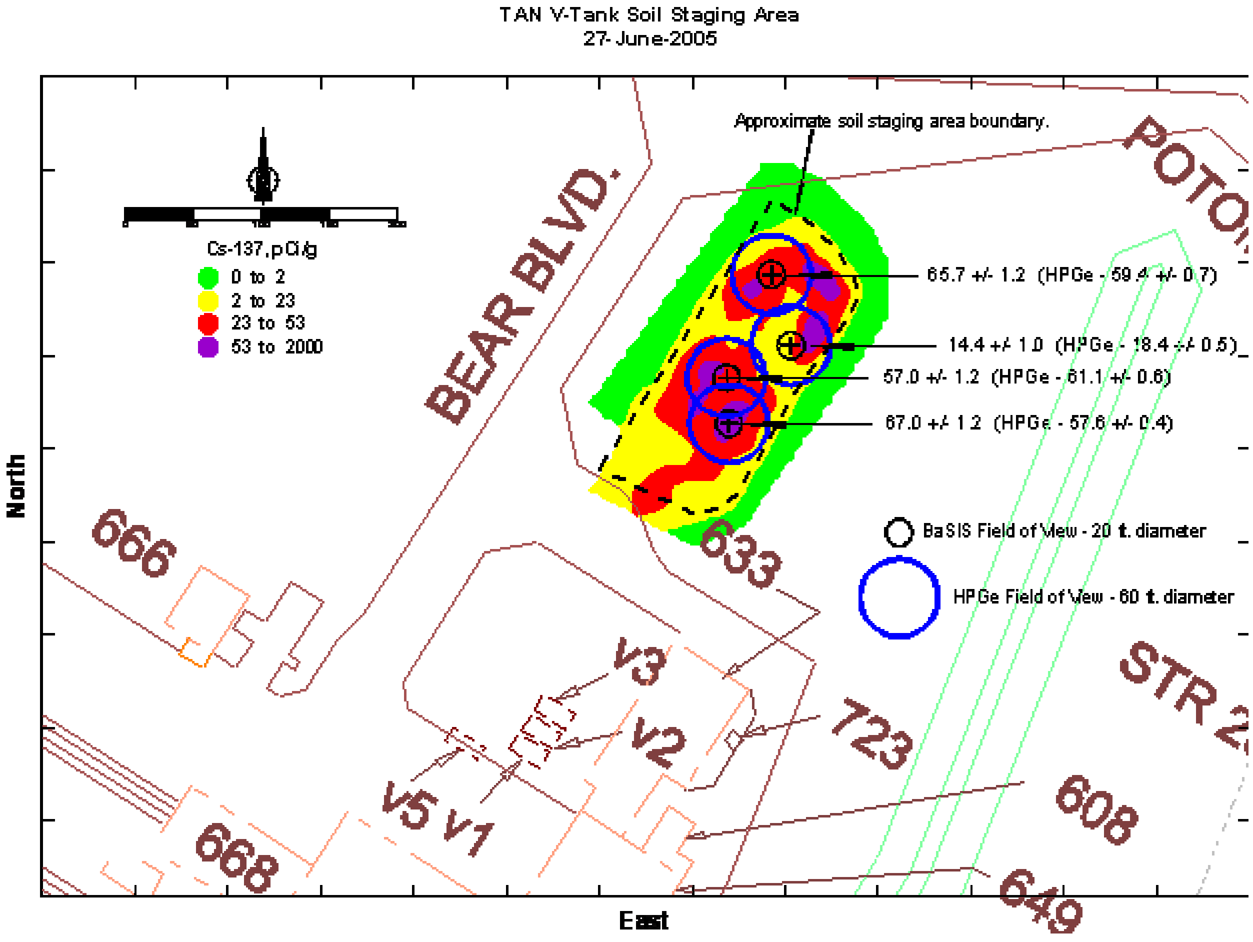

Fig. 3. BaSIS field test results

As shown by the Cs-137 contours in Fig. 3, the BaSIS was used to provide a 100% coverage survey of the soil stockpile area, and the area immediately surrounding it. The survey shows that the area surrounding the access-controlled stockpile area has Cs-137 concentrations below 2 pCi/g, while the stockpile area contains Cs-137 at concentrations above the free-release criteria of 2.3 pCi/g with more than half of the area at concentrations exceeding the CERCLA risk-based remedial action goal of 23 pCi/g.

Figure 3 also shows the locations of the four points used for the comparison measurements between the BaSIS and HPGe systems. For these measurements, BaSIS was operated in the point-and-shoot mode with count times of 5-minutes at each location. A direct comparison of the reported activities for these four locations is provided in Table III, showing that the highest relative difference occurred at point T3. This can be attributed to the higher degree of heterogeneity of Cs-137 distribution within the fields of view of the two systems at this location. The other three locations, T1, T2, and T4, showed very good agreement between the two systems, with no apparent bias.

Table III. Results of Comparison Study Between BaSIS and HPGe Measurement Systems

Point ID	**BaSIS – Cs-137, pCi/g**	**HPGe – Cs-137, pCi/g**	**Relative Percent Difference**
T1	57.0 +/- 1.2	61.1 +/- 0.6	6.9%
T2	65.7 +/- 1.2	59.4 +/- 0.7	10.1%
T3	14.4 +/- 1.0	18.4 +/- 0.5	24.4%
T4	67.0 +/- 1.2	57.6 +/- 0.4	15.1%

The results of the BaSIS field testing successfully demonstrated the operability of the system, and acceptable comparability (i.e., relative percent difference of 25% or less) with the HPGe system that has been the baseline technology for field measurements. These results were presented and discussed with the Agencies, and approval was obtained from the Agencies to proceed with use of the BaSIS for real-time remediation. It should be noted that although the field of view for the BaSIS system (314 ft^2) is considerably smaller than that of the HPGe (2,827 ft^2), this area was surveyed (100% coverage) in roughly one-half hour; whereas the four HPGe measurements were 15-minutes each. If the HPGe system was used to provide a 100% coverage survey it would have required 10 measurements and approximately 2.5 hours to complete, not including the data analysis.

REAL-TIME REMEDIATION

Upon completion of the calibration and field-testing of the BaSIS system, the concept of real-time remediation was implemented at the Idaho Cleanup Project (ICP) in support of soil remediation projects. Real-time remediation, as implemented at the ICP, is comprised of dynamic work plans, specialized radiation measurement equipment, and prompt reporting of results to expedite the decision making process in the field.

The initial testing of real-time remediation occurred at a site that had previously been remediated. Subsequent surveys of the area with the BaSIS identified residual Cs-137 contamination at concentrations exceeding the 23 pCi/g remedial action goal. Figure 5 depicts the cycle of the real-time remediation process at the site, which took approximately 4-hours, from the marking of the excavation area to the final backfill. The excavation area boundary identified here is roughly 8 ft. wide by 40 ft. long. This area was identified and marked in the field using the BaSIS, and the area excavated to a depth of approximately 12 in. After the initial excavation, BaSIS was used to survey and identify any locations that exceeded the 23 pCi/g remedial action goal. One spot was found at the northwest boundary of the excavation. A small quantity of material was removed from this location, and a subsequent survey confirmed that Cs-137 concentrations in the soil were below the 23 pCi/g remedial action goal. The area was backfilled to pre-excavation grade, and the contaminated soil dispositioned at an on-site disposal facility.

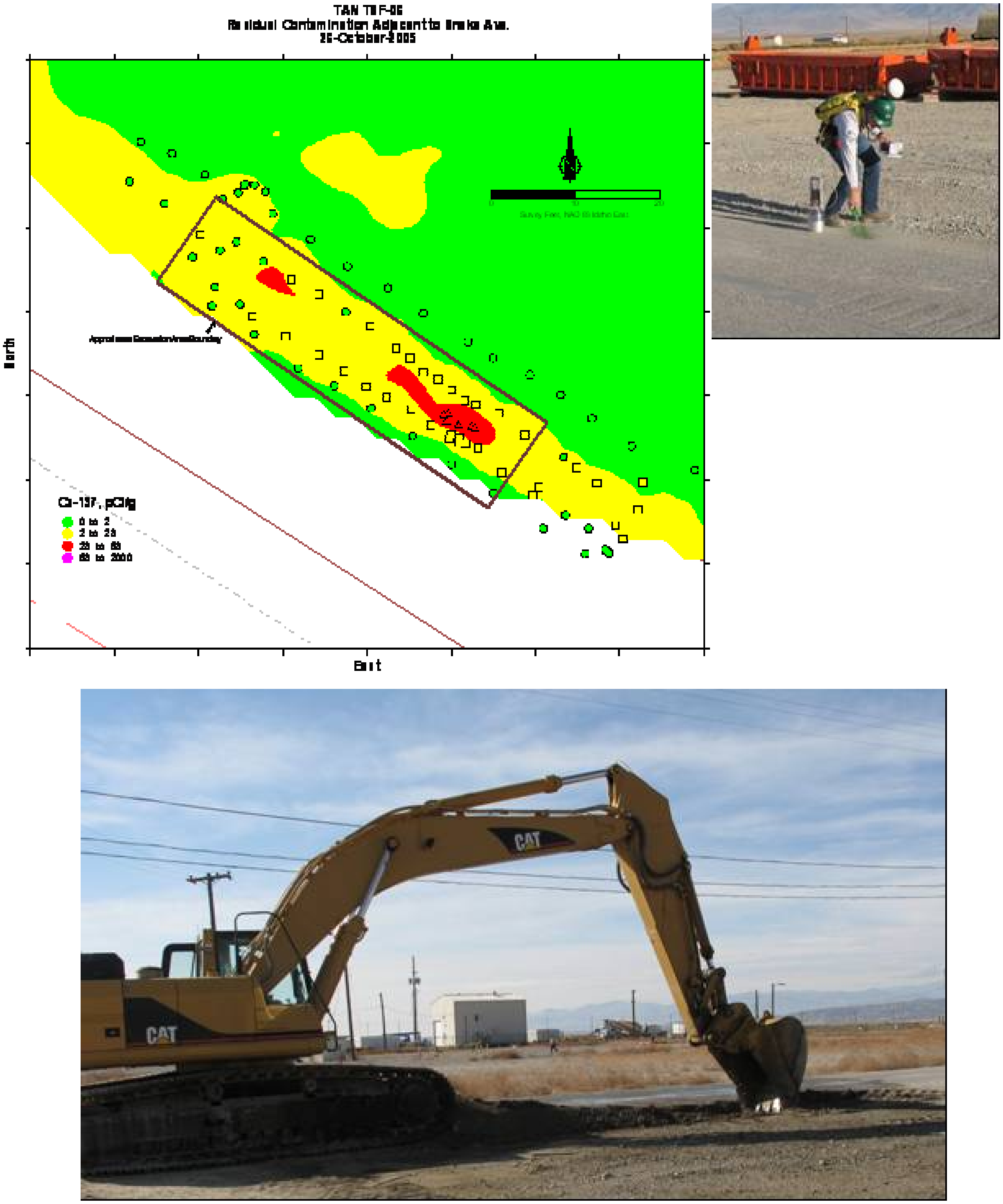

Fig. 5. Real-time remediation process showing the pre-excavation survey, marking of the excavation boundary, removal of contaminated soil

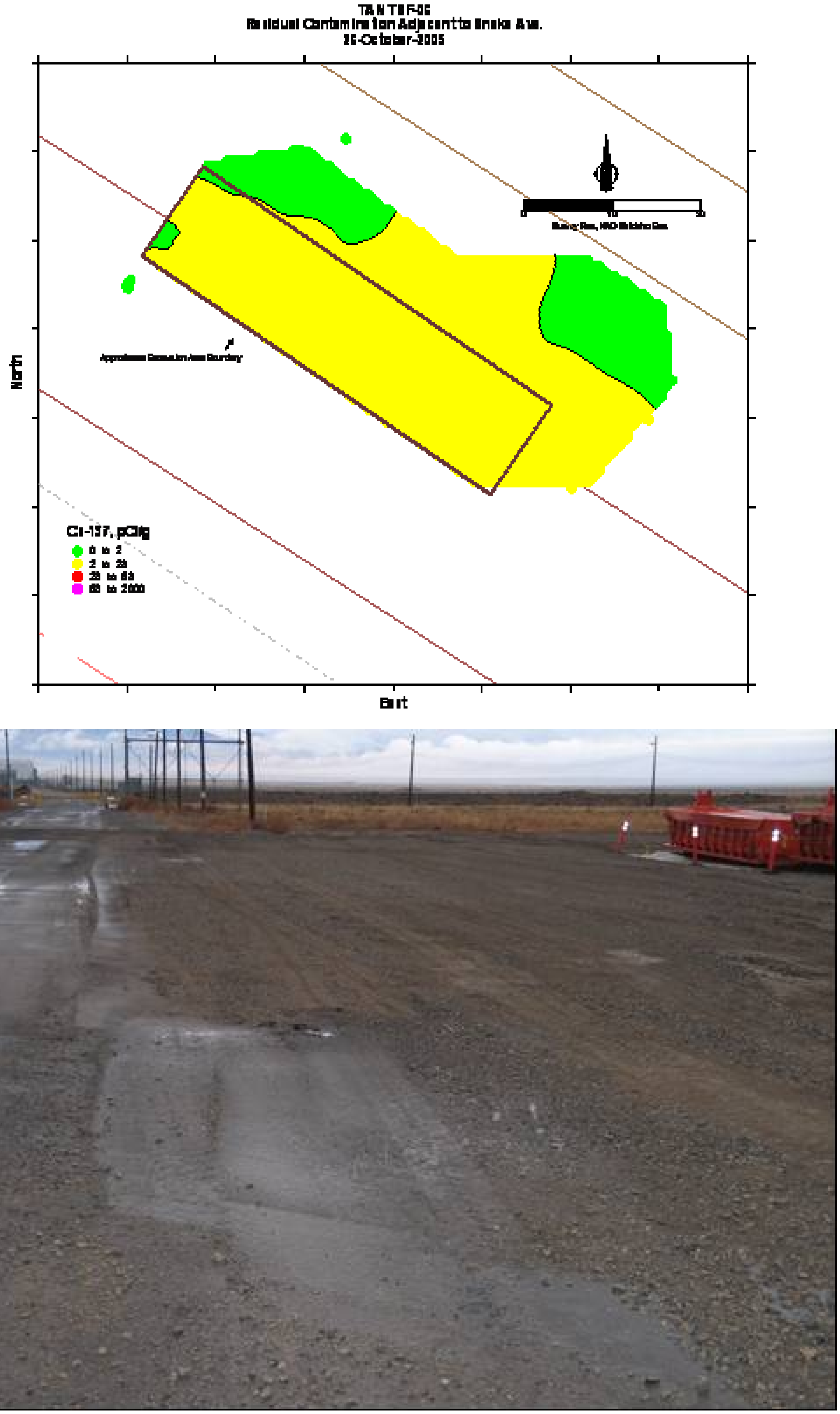

Fig. 5. Real-time remediation process showing post-excavation survey and the backfilled area.

CONCLUSION

The BaSIS was developed and deployed to be used during remediation activities at the TAN site at the INL in support of soil remediation activities. Although the first attempt at real-time remediation was at a relatively small site, it allowed ICP and INL personnel to prove the concept of real-time remediation using the newly developed BaSIS radiation survey system. Development and use of the BaSIS has demonstrated that 100% coverage surveys for Cs-137 contamination in soils can be completed efficiently and accurately. The survey of a given area with the BaSIS can be completed in less than one-quarter of the time required when using an in situ HPGe detector system. Additionally, the ability to provide real-time Cs-137 concentrations in soil significantly minimizes idle time in the field. Use of the BaSIS during remediation activities provides project personnel with the capability to make rapid and accurate decisions, without having to wait for laboratory analytical results. This, in turn, increases the overall efficiency of the remediation process.

REFERENCES

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